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MACS, THE MANIPULATION AND COLLIMATION SYSTEM ON THE NPD AT LANSCE

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ABSTRACT. The practical problems associated with beam collimation and specimen manipulation at a pulsed neutron source are identical to those on a steady state source. However extra constraints result from the limited space available and from the time of flight analysis of the diffracted neutrons. A manipulation and collimation system (MACS) has been designed for the neutron powder diffractometer (NPD) at the Los Alamos spallation neutron source (LANSCE). It provides specimen motion and aperture positionning with accuracies of better than 0.1mm and is constructed as a rigid unit. For flat sided specimens sampling volumes less than $30mm^3$ have been obtained demonstrating the viability of making spatially resolved strain measurements at a pulsed neutron source.

1. Introduction

Spatially resolved measurement by neutron diffraction of residual lattice strains are made at different positions in a component by translating it through a defined sampling volume. Strains in different directions are measured by reorientating the specimen with respect to the detectors. Thus the basic requirements for a measuring system are multi-axis specimen manipulation, precise collimation of the neutron beams and an ability to place a specimen accurately relative to a reference point. In engineering applications the sampling volumes of interest are often less than $50mm^3$ except when a symmetry can be assumed or when spatially resolved measurements are not required. In situations involving steep stress gradients sampling volumes of less than $10mm^3$ are sometimes necessary. Despite the small sampling volumes the mass of specimens can vary from a few hundred grammes to tens off kilograms. A final requirement is that the sampling volumes can be rapidly and accurately changed for different experiments.

The requirements are necessary both for pulsed source and steady-state sources. On POLARIS at ISIS in the U.K. and on the NPD at LANSCE in the U.S. the sample position lies within steel vacuum vessels which are normally evacuated during experiments to minimize air scattering. On the NPD the vacuum vessel is surrounded by bulk shielding which cannot be removed (unlike POLARIS) and precludes any optical access to the specimen when it is in position for measuring a spectrum. The sample position is on the axis of the circular opening in the top of the vacuum vessel at a specified height below the top flange corresponding to the centre of the neutron beam. When the specimen is in position it is surrounded by four banks of detector at ± 90° and ± 148° which provide 4 simultaneous strain measurements although the best volume definition is achieved with the 90° detectors.

2. Translators

The diameter of the circular opening in the vacuum vessel of the NPD is 74cm. All collimation and manipulators must pass through this opening. The approach on the NPD has been to mount the manipulators and beam apertures into a rigid frame attached to a top plate which can be placed precisely in the instrument using cone locators. Prior alignment is possible in a copy of the instrument sample can to which optical access is possible.

The minimum requirement for the specimen movement system was XYZ orthogonal translation and a rotation about a vertical axis. However the necessity that the system passed through the round aperture constrained the design and limited the extent of the movements particularly in the two horizontal directions. Lowering specimens into the beam would require a clamp which can accomodate many different specimen sizes and masses. For light specimens this is not a problem, however massive specimens of unusual shape can more conveniently be supported on a flat surface and raised into the neutron beam. Consequently vertical motion is provided by raising or lowering a flat table on 4 shafts which are interconnected by a drive chain. This provides 300mm of vertical motion between the beam height and the top of the rotary stage

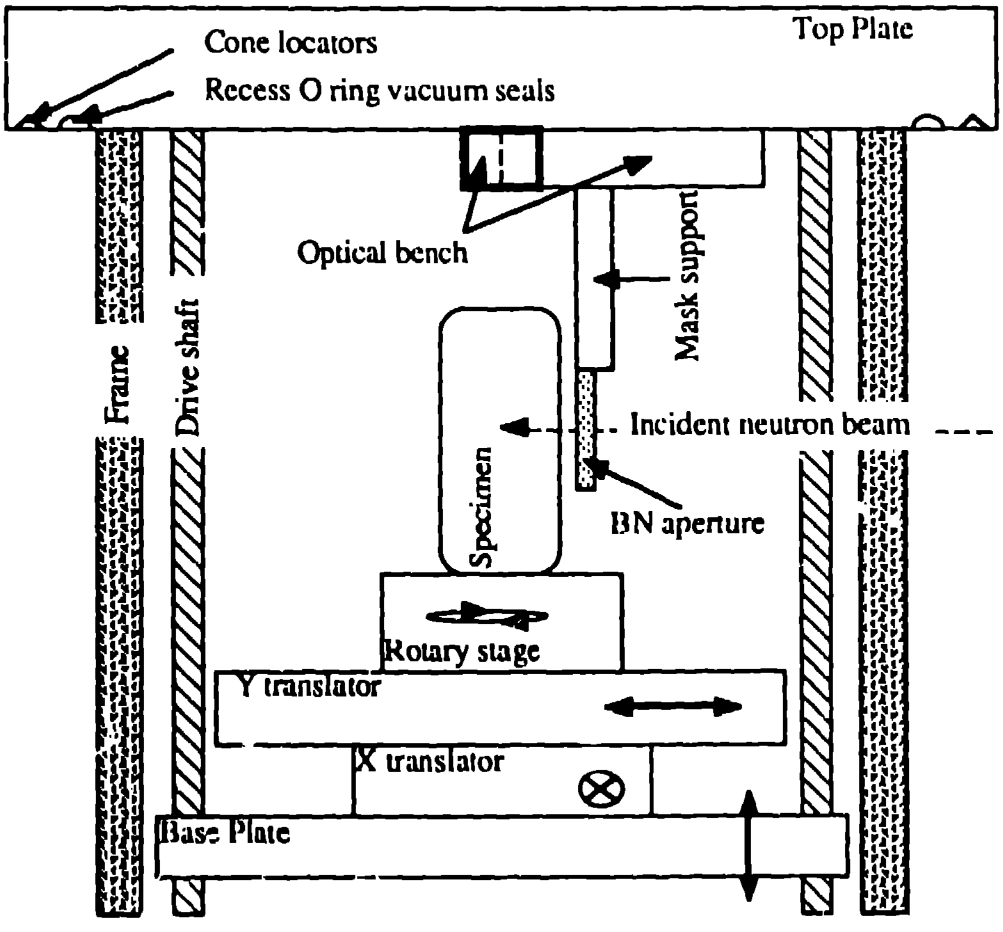

Figure 1:. Schematic of MACS equipment

..Horizontal translators are mounted parallel and normal to the incident beam direction. To move a specimen along the scattering vector for one of the 90° banks , i.e. at 45° to the incident beam, (which is frequently necessary) the translators are operated sequentially to give a zig-zag motion. Smooth motion along the scattering vector is advantageous and can be obtained by simultaneous operation of the motors. The horizontal slides each provide a total travel of 25 cm. Together with the vertical motion the MACS system can accomodate specimens up to 50kg. A schematic of the manipulation system is included in figure 1. Figure 2 shows a $(300mm)^2$, 25mm thick weld specimen (RS-1 in the photo) in position in the MACS system.

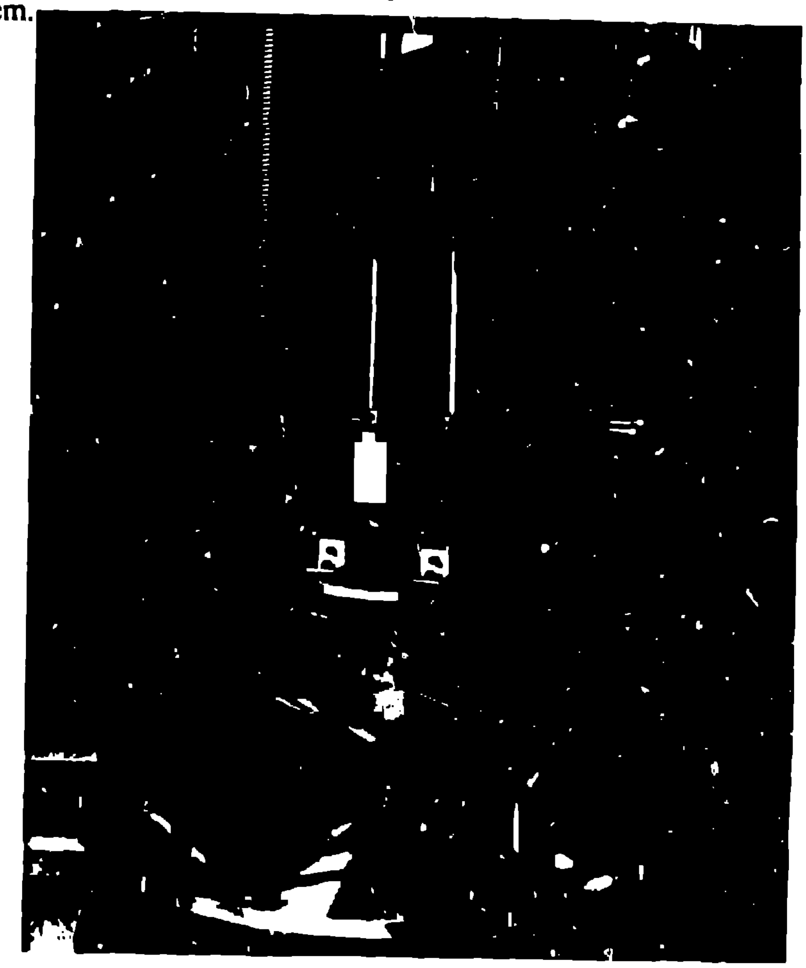

Figure 2: Photograph of MACS equipment with $(300mm)^2$ 25mm thick weld (RS1) in position for measurement

3. Collimation

On monochromatic diffractometers which scan the diffracted intensity as a function of angle the direction of the diffracted beam must be accurately defined at the detector. Consequently collimation is inherent between the specimen and the detector in the form of soller slits. This facilitates the definition of a sampling volume because a slit can be installed anywhere between the sample and the detector. On a pulsed source there is no inherent collimation between the specimen and detectors and diffracted neutrons can reach the detector from any scattering geometry. Care must be taken in masking the specimen so that only neutrons from the sampling volume reach the detector.

The uncollimated incident beam on the NPD is approximately 50mm high and 10mm across. The sample position is 32m from the tungsten target (where the neutrons are produced) and consequently the divergence of the incident neutron beam at the sample position is small. Hence the distance between the incident aperture and the specimen does not affect the definition of a sampling volume. The penumbra at the sample position around a beam defined by a 2mm square placed 50mm from the specimen is less than 0.2mm both vertically and horizontally. Thus collimation of the incident beam is not strongly related to the distance of the incident aperture from the specimen.

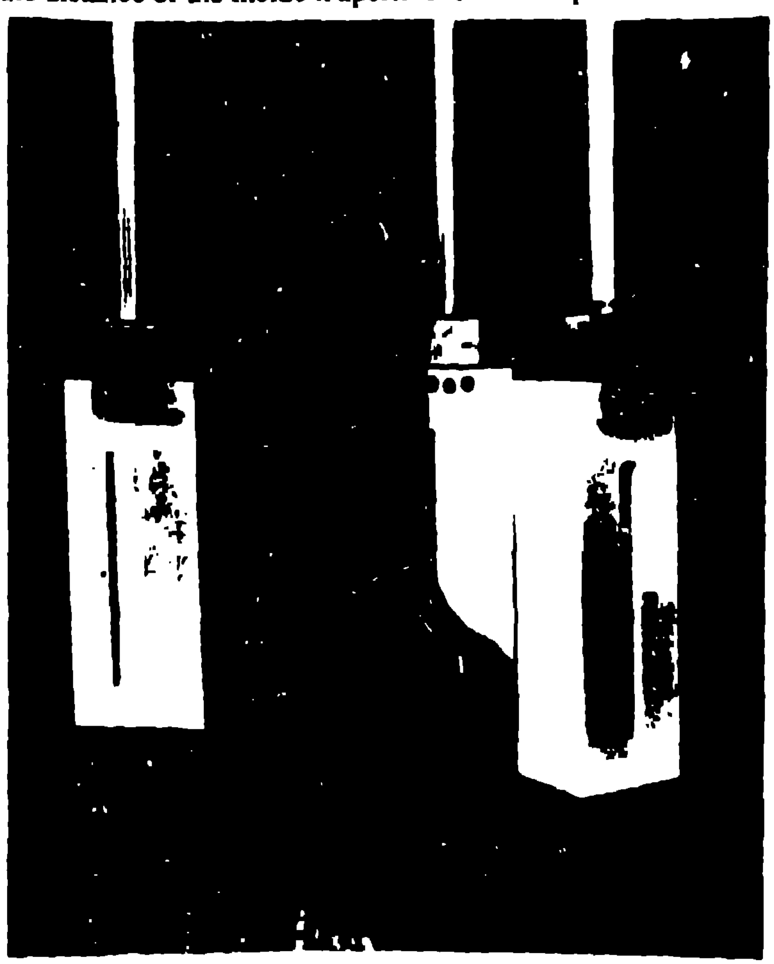

Figure 3: BN apertures by connecting rod.

The situation for the diffracted beam apertures differs because close proximity between the aperture and the incident beam direction is necessary. Although a thick aperture placed 10cm from the specimen could give millimeter spatial definition along the incident beam it would necessarily obscure a large solid angle of the 90° detectors which subtend $\approx 11°$ at the sample. Count rates for sampling volumes less than $100mm^3$ necessitate that most or all of the detector solid angle is employed if the use of the beam time is to be acceptable. Good spatial resolution along the incident beam can only be obtained while maintaining a large solid angle of detector by having close proximity of the diffracted beam apertures to the incident beam. The best spatial resolution is achieved for flat plates where the apertures can be placed directly adjacent to the surfaces.

Both the incident and diffracted apertures are supported from slides on optical benches which are attached to the underside of the top plate (fig 1). The rails are aligned parallel with and normal to the incident beam direction. This allows the apertures to be moved to different radii from the centre of the sampling volume without any lateral displacement. Fine positional adjustment is performed using manual microcontrol adjusters.

At a spallation source the wavelength spectrum in each pulse is continuous and boron not cadmium is used as a mask because it doesn't have a short wavelength cut off and remains opaque to neutrons below 0.5Å. Boron nitride proved to be preferable to boron carbide because it was easier to machine to precise dimensions. A variety of apertures were fabricated from a 13mm thick Boron nitride plate. Incident apertures are taylored to specific requirements by combining vertical and horizontal slits. Figure 3 shows a photo of a connecting rod surrounded by the white BN apertures. For clarity the 90° masks have been withdrawn from the specimen but in practice they would be adjacent to the specimen surface.

4. Calibration

The sampling volume is defined at a point in space at the intersection of the incident and diffracted beams. The position is arbitrary thus calibration of the detectors is important if the absolute values of the lattice spacings obtained from different banks are to be consistent. To calibrate the detectors the diffracted spectrum for a well characterised stress free powder is measured by the defined sampling volume From knowledge of the structure of the powder, the calibration constants (which relate the time of flight to the wavelength) for each detector can be determined. If the centre of the sampling volume is unmoved for different aperture combinations the calibration remains effective. However if an aperture is displaced and the centre of the sampling volume moved then recalibration will be necessary. For this reason the apertures must be accurately replacable and movable along directions which are either parallel or normal to the incident beam direction to avoid repeated recalibration.

Intensity checks were made by translating a vertical steel pin through the sampling volume defined by different aperture sizes and positions. The diffracted intensity over a specific wavelength range was noted as the pin was moved parallel and normal to the incident beam. When the pin was moved normal to the incident beam direction the intensity profiles showed sharp reductions at the limits of the aperture size indicating the parallel nature of the incident beam. Intensity scans were also recorded in the 90° detectors as the pin was moved parallel to the incident beam. Knowledge of the angle subtended by the detectors combined with the width, thickness and distance of the apertures from the incident beam allowed the resolution along the incident beam to be predicted

5. Future development

A displacements of the sampling volume by only a few millimeters may be misintepreted as a strain variation due to the change in path length and commensurate error in calibration. Previously alignment procedures were performed by dead reckoning but we are installing two alignment telescopes on the dummy sample can which will ensure that apertures and specimens are replacable to within 0.1mm for concurrent measurements. A transmitted beam monitor will also be installed to aid in aligning specimens by noting the change in the ratio of the transmitted to the incident beam intensity as the specimen is moved into the beam.

6. Conclusions

A manipulation and collimation system has been installed on the NPD at LANSCE. Components up to 50kg can be moved within the confines of the sample tank. Sampling volumes as small as $10mm^3$ have been achieved for thin flat samples. However for specimens where the exit collimation cannot be placed within 30mm of the incident beam it is impossible to get get good spatial resolution along the incident beam without obscuring part of the 90^o detector bank and compromising the count times. Optimum spatial resolution is obtained by installing the diffracted beam apertures adjacent to the specimen surface or as close as allowed by the geometry of a particular measurement. This makes flat sided specimens where strains are required at different positions in the plane of the specimen most suitable for measurements on a pulsed instrument.

7. Acknowledgements

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